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JOHN F. KENNEDY SPACE CENTER

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MATERIALS ANALYSIS BRANCH
SOP-41

MATERIALS TESTING AND MALFUNCTION INVESTIGATION CAPABILITY

Prepared by
Materials Analysis Branch
Test and Calibration Division

KSC FORM 16-12 (1/64)

FOREWORD

The Materials Analysis Branch (MAB), Materials Test and Calibration Division, John F. Kennedy Space Center (KSC), is a highly specialized fact finding organization oriented to laboratorial investigation of malfunctions and analysis of failures of components and materials on spacecraft, launch vehicles, and ground support equipment (GSE) hardware.

The MAB was established in 1962 to investigate failures related solely to manned spacecraft hardware. However, with the consolidation of the laboratories into KSC, the problem related work commitment of the MAB was expanded to include work with all hardware under KSC cognizance.

A team of capable specialists has been assembled and team experience has been gained on a broad spectrum of time critical functions. These specialists along with the facilities of an effectively equipped laboratory and advanced testing methods have come to be considered the most powerful post-failure investigative complex ever assembled.

The MAB services, as outlined in this document, are available both collectively and on an individual basis, for post-failure evaluation of components, materials and hardware. However, the requestor most often can be served best by an investigation to determine the cause rather than by an individual specialization within the MAB.

Through the investigation to determine the cause approach, the requestor avails himself of a professionally coordinated laboratory sequence, with priorities which produce the best possible answer in a minimum time. The investigation is never closed to the requestor, and he may follow his hardware through the laboratory as he desires.

Through the individual specialization approach, the requestor specifies the scope and limitations of a needed service. Although, he will receive the best investigation or analysis achievable he will be burdened with the responsibility for correctly specifying his need and for relating the answer to the problem. The laboratories offer many services which in themselves amply serve the need. Routine x-ray work, for example, may be specifically needed and all that is needed. Service of such singular purpose will be supplied as requested.

The requestor will find the MAB to offer an efficient and capable service. This document is intended to aid the requestor in determining what the MAB is committed to, what it can do for him, and how to best apply its services to his need.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

SECTION I
INTRODUCTION

1.1 PURPOSE

The purpose of this document is to explain the capabilities of the Materials Analysis Branch, the equipment available, and to outline the methods by which requestors can best apply its services.

1.2 SCOPE

This document presents the operating philosophy of the Branch and describes its mission, the services it provides, and its capabilities. The document also includes a concise description of the equipment and facilities utilized to conduct investigations, analyses, and tests.

1.3 CHARTER CONCEPT

The Materials Analysis Branch will carry out this task through the provision of NASA-Materials Analysis Branch Laboratories, NASA Staff, Contractor Staff operating under the technical direction of the Materials Analysis Branch Chief, technical control of prime contractor's representatives assigned to the Materials Analysis Branch Laboratory areas and acquisition of outside support services to Materials Analysis Branch specifications.

The Materials Analysis Branch shall carry out the Center's interest in the areas described in the following paragraphs. (The charter refers to future actions since it was an initiating document. Almost all activity authorized is now in productive use.)

1.3.1 Materials Testing

The Materials Analysis Branch will conduct materials tests for all materials which may come into KSC control. These tests will be conducted upon request from the cognizant KSC element. The specialists will work with the requestor to assure that the final product of the work is oriented to purpose.

Materials testing will be oriented to all ASTM methods but the Materials Analysis Branch will be prepared to conduct special tests where ASTM methods and evolved information is not adequately related to purpose.

No attempt will be made to equip at KSC for all possible tests. Where advisable to do so such service will be acquired from outside laboratories. Arrangements for such action will be a function of the Materials Analysis Branch.

1.3.2 Materials Application Technology

All materials problems of which KSC has cognizance may be referred to the Materials Analysis Branch. This activity will be a two part operation having no discontinuity. Information will be provided by (1) close coordination with research centers for information and (2) production of information, by tests, which is not otherwise available.

Materials information will be provided in full spectrum from gross materials to the molecular mechanics of materials. This will involve materials as to basic physical nature, materials as shapes, materials as alloys, materials as mixtures (such as infiltrated powder metals), materials as composites (such as fiberglass), and materials systems (such as structural radiators, foam/skin structures, etc.).

1.3.3 Non-Destructive Testing

The Materials Analysis Branch will conduct all non-destructive tests as requested by NASA agencies and contractors whose operations are under KSC cognizance. This will include the following areas:

a. X-Ray, Field and Laboratory
b. Gamma Ray Radiography
c. Ultra-Sonic Testing
d. Eddy Current Testing
e. Magnetic Particle Testing
f. Dye Penetrant Testing
g. Brittle Lacquer Testing
h. Strain Gage Analysis Work
i. Infra-Red Thermography (Will be active in FY '67)

The Materials Analysis Branch will not equip to conduct all possible tests if satisfactory local testing service can be acquired. It will be the Materials Analysis Branch, however, that will maintain cognizance of such outside service and coordinate it with their own in-house work.

1.3.4 Failed Parts Analysis

The Materials Analysis Branch will conduct failed parts analysis for those NASA organizations and contractors operating under the cognizance of KSC. This will be done on an "as requested" basis. The areas covered will include all manned spacecraft, unmanned spacecraft, stages and ground support equipment.

All Analysis work done in the Materials Analysis Branch Laboratories will be under the control of Material Analysis Branch specialists, but any requestor personnel informed on the device and/or circumstances of failure will be encouraged to participate to a maximum degree in the analysis.

The Material Analysis Branch will equip and staff for professional failure analysis work and will assure that all factors and persons contributing to such analysis are so employed that reliable and useful information evolves.

1.3.5 Malfunction Investigation

(By definition malfunction investigation encompasses failed parts analysis and continues the identification of the causal chain to the initiating technical elements of causality.) The Materials Analysis Branch will conduct malfunction investigation related to all hardware subject to KSC cognizance on an "as requested" basis. Once requested to investigate, the Materials Analysis Branch will provide technical direction for the full scope of that investigation. The requestor will be advised if it is apparent that the cost of full investigation is not justified in particular cases.

When full investigations are requested and justified, information which results will be reviewed for value in the general science of spaceflight. If appropriate, a Malfunction Investigation Report (MIR) will be issued.

All investigative work related to hardware problems referred to the Materials Analysis Branch will be under the control of the Materials Analysis Branch, but all interested parties will be encouraged to participate to the maximum extent commensurate with professional investigative practices.

1.3.6 Environmental Testing

The Materials Analysis Branch will administrate the local environmental testing activity for KSC. The Materials Analysis Branch will equip and staff to deal with a scope of expected work and will maintain contact with outside service laboratories for work not done in-house. The in-house and outside service proportioning will be designed to yield maximum advantage to the government.

Testing will include but not be limited to:

a. Vibration
b. Shock
c. Vacuum
d. Temperature
e. Humidity
f. Pressure
g. Dust
h. Salt Spray

Special tests will be devised for special purposes, for instance, where environments and operating characteristics must be concurrently related.

1.3.7 Quality Physics Review

The Materials Analysis Branch will conduct those tests for the KSC quality organizations that determine the value of routine quality verification activities in assuring the achievement of established quality levels.

This will be done on an "as requested" basis in response to KSC quality organization requests.

1.3.8 Space Science Experiment Support

The Materials Analysis Branch will provide the laboratory support required for on-board space experiments. This will include work with the space experiments program office devised to bring space experiment functional hardware support into line with the practical demands of compatibility with pre-launch activities. Where necessary, laboratory tests will be augmented with qualification testing and response to project office request for remedial action information.

Materials application technology will be provided to the project office upon request and special tests will be conducted upon request for the evaluation of alternate methods.

1.3.9 Impending Failure Detection

The Materials Analysis Branch will exploit its access to devices exhibiting known failure characteristics to evaluate and devise methods for non-destructive determination of approaching failure in functioning devices.

This may be expected to follow the lines of sound signature analysis and infrared thermography.

The objective of this work is to acquire the ability to detect degradation of operating devices in pre-launch testing. A secondary consideration will be the development of the ability to detect degradation and estimate rate of degradation with on-board equipment in flight.

SECTION II
ORGANIZATION

2.1 GENERAL

The Materials Analysis Branch consists of three operating sections and laboratories (Figure 2-1). The sections have been designated:

Malfunction Investigation Section
Malfunction Investigation Support Section
Materials Test Section

The laboratories within each section, as a composite group, have capabilities which encompass all the facets of malfunction investigation, environmental testing, and physical testing described in the charter concept.

The individual laboratories contain specialized equipment and instruments oriented to their particular area of specialization. Because tests and investigations in many instances cross laboratory boundaries, branch personnel are cross-trained in terms of the principals of operation and capabilities of instruments. Cross-training among specializations enables the investigator to best know when the counsel of other specialists should be sought.

The functions and responsibilities of each laboratory are described in the following paragraphs. The capabilities and operating parameters of their equipment and facilities are described in Section III.

The MAB is committed to respond to emergency situations and, where justifiable, its services will be made available at any time. During normal working hours, calls should be made directly to the MIL phone number 867-7048, 49, or 50. This laboratory is in room 1420 of the Manned Spacecraft Operations Building in the Industrial Complex on Merritt Island.

When the laboratory is not open, the following people may be contacted:

1. John Jeter Phone 636-7635 (30 minutes from MSOB)
2. Ralph Yorio Phone 773-1487 (45 minutes from MSOB)
3. C. F. Warnock (Tieline 867-7111) 425-7057 (45 minutes from MSOB)
4. Drew Evans (Tieline 867-7111) 365-3703 (40 minutes from from MSOB)

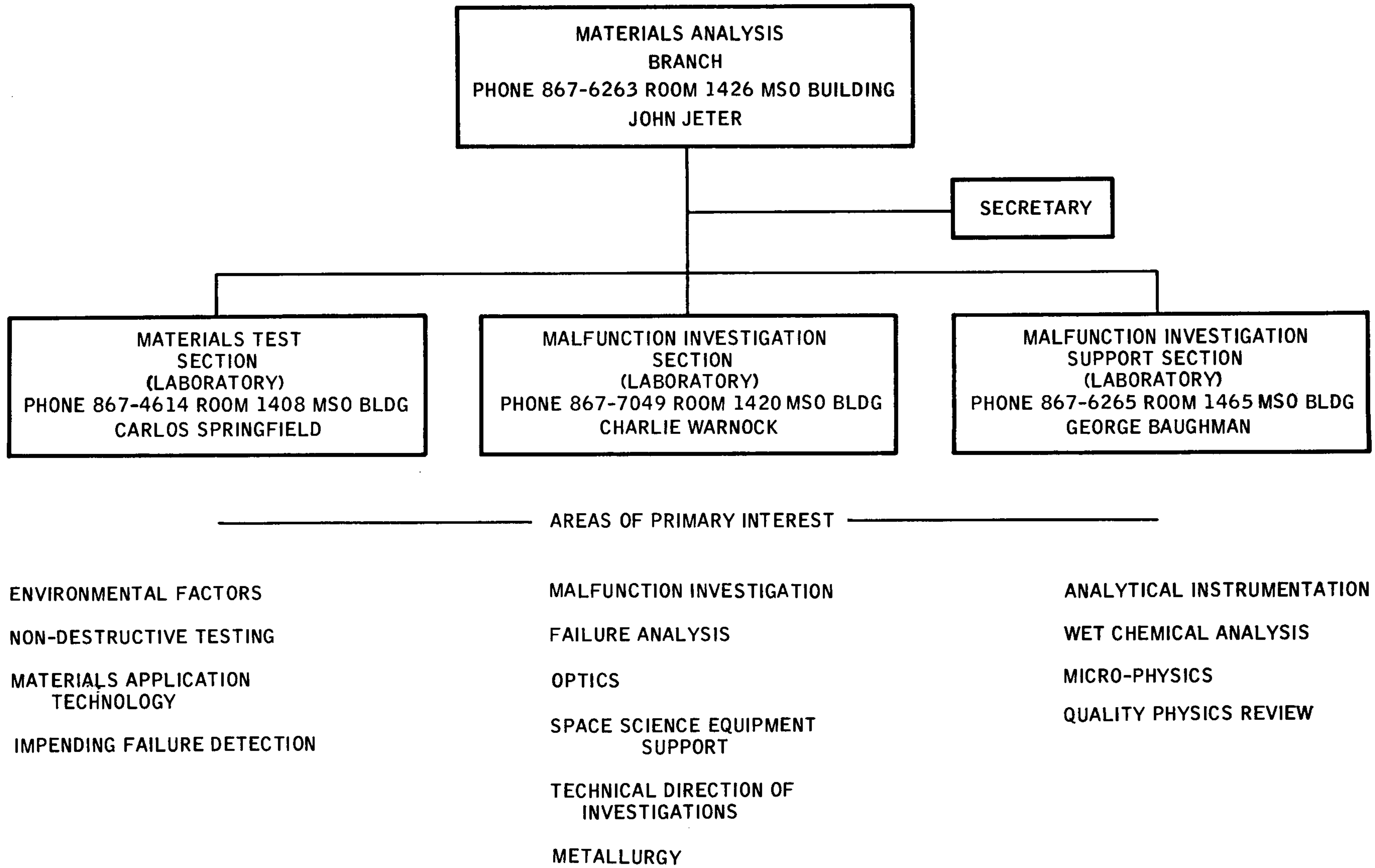

Figure 2-1. Materials Analysis Branch Organizational Chart

If problem is known to be chemical in nature:

a. John Jeter Phone 636-7635
b. George Baughman Phone 632-1204 (30 minutes from MSOB)
c. Lloyd Bostwick Phone 632-4117 (30 minutes from MSOB)

If need lies in area of non-destructive testing, materials test or environmental tests:

a. Carlos Springfield Phone AM7-3725 (40 minutes from MSOB)
b. William Paton Phone 267-4322 (40 minutes from MSOB)
c. John Jeter Phone 636-7635

In answer to the inevitable question, the MAB laboratory equipment will not be placed in the hands of anyone not checked out on the equipment and normally permitted to operate it.

2.2 MALFUNCTION INVESTIGATION SECTION

The malfunction investigation section is the MAB entry point for all failed parts analysis and investigative work. All work, contributing to an investigation, done by other MAB sections and outside services is controlled by this section and the resulting records are retained there. This section relates the various forms of information to the problem at hand.

Malfunctioned components and materials submitted to the branch normally receive their first inspection in the Malfunction Investigation Section laboratory. This inspection may be a cursory visual inspection to determine which laboratory within the branch will perform the actual investigative work, or it may entail a complete investigation, using the laboratory's clean room, its special effects photography, and radiographic technology.

Interface problems that may have caused a failure or malfunction are investigated and analyzed by the laboratory prior to any disassembly operation. X-ray image intensifiers and cine-radiography are used to observe and study the motions of parts that are hidden from view inside assemblies or potted compounds.

Nationwide liaison is maintained by the Malfunction Investigation Section with other governmental agencies, and with industry, to ensure up-to-date testing techniques and information relative to components and materials in components are available to the branch.

2.3 MALFUNCTION INVESTIGATION SUPPORT SECTION

The Malfunction Investigation Support Section laboratory analyzes and identifies materials and their chemical and physical characteristics to determine the specific causes of failure to spacecraft, launch vehicle, and GSE hardware.

The laboratory is staffed and equipped to conduct qualitative and quantitative chemical analysis of materials and compounds. The equipment ranges from that found in conventional laboratories for conducting analyses bythe classical wet chemistry procedures, to the more sophisticated conventionally research-oriented instruments for conducting analytical studies on quantities of material ten to thousands of times smaller than is possible by wet chemical procedures.

For all practical purposes, the laboratory is separated into two functional areas, each an entity into itself but so closely interwoven with the other in the overall scope of the mission that an inseparable composite is formed. The functional areas are: Analytical Instrumentation, and Wet Methods.

Supporting equipment used in conjunction with the above areas includes such equipment as necessary for the preparation of samples for microscopic and analytical examination, and various spectra files, x-ray powder data files, and comparison standards.

2.4 MATERIALS TEST SECTION

The Materials Test Section is responsible for environmental tests and non-destructive tests on components and materials which may come into KSC control, and for maintaining a materials application technology file on such components and materials. Local materials formulation, compounding and testing will supplement available information when demanded due to center related materials problems.

To provide the capabilities specified in the charter concept (1.3) for this section, testing facilities and equipment are separated into three independent, though interrelated, laboratories: the Environmental Factors Laboratory, the Non-Destructive Testing Laboratory, and the Materials Application Technology Laboratory.

2.4.1 Environmental Factors Laboratory

The Environmental Factors Laboratory is responsible for carrying out environmental simulations for investigative work performed by the Materials Investigation Laboratory, and for conducting qualification tests and environmental tests for other organizations.

The climatic and dynamic environmental factors to which spacecraft, launch vehicles, and GSE hardware may be exposed, and which can be simulated in the Environmental Factors Laboratory include, but are not limited to, vibration, vacuum, shock, heat and thermal radiation, and acceleration.

This laboratory has the capability of conducting expedited investigative work that cannot be duplicated in existing conventional laboratories because of its advantageous physical location, aerospace oriented equipment, and availability of personnel involved in the investigation.

The branch philosophy that each malfunction is of an unexpected nature, and that the Malfunction Investigation Section must determine the cause of a failure and recommend remedial action immediately, makes the Environmental Factors Laboratory a significant contributor to the investigative services provided by the branch.

Services of this laboratory are available for work of the environmental test nature, to specifications, independent of investigative work.

2.4.2 Non-destructive Testing Laboratory

The Non-Destructive Testing Laboratory was established to provide the Materials Analysis Branch with the capability for determining the condition of components and materials without disturbing or destroying the construction or configuration of the item under test.

Originally created to perform non-destructive tests on spacecraft hardware, the laboratory has expanded its capability to include launch vehicle and GSE hardware, and facilities equipment. NOT service is available independently of investigative function.

The Non-Destructive Testing Laboratory, because of its ability to detect random discontinuities through indirect testing methods, provides invaluable support to the Malfunction Investigation Laboratory. Its portable x-ray and gamma ray radiographic equipment can be used at launch complexes as an aid to failure analyses on spacecraft and launch vehicles. For example, the 200 KVP portable x-ray unit can determine many internal features of an electronic component in a spacecraft quickly, and without requiring the removal of access panels or other components that could delay the countdown, or interrupt scheduled tests. In such cases, the investigator arranges for NOT work, assures its orientation to purpose and interprets result.

With the equipment available at this time, the Non-Destructive Testing Laboratory can offer the following services:

Radiographic Testing
Magnetic Particle and Liquid Penetrant Tests
Ultrasonic and Sonic Tests
Eddy Current Tests

The brittle lacquer and strain gage work is done by engineers of the MTL.

SECTION III
FACILITIES AND EQUIPMENT

3.1 GENERAL

The information presented in this Section describes the facilities and equipment currently present in the Materials Analysis Branch. The charter concept for the branch can be fully implemented with the existing facilities and equipment; however, as the state of the art of malfunction investigation and post-failure analysis progresses, adjustments will be made to ensure the laboratories have whatever equipment is necessary, consistent with branch requirements, of course, to maintain the high rate of performance they have established. The individual services available from the MAB will similarly be adjusted for alignment with purpose.

3.2 MATERIALS TEST LABORATORY

3.2.1 Clean Room (Figure 3.2-1)

A clean room is an enclosed area which employs control over the particulate matter in air with temperature, humidity, and pressure control as required. It is designed to provide the environmental control necessary for the disassembly, test, and reassembly of components and assemblies whose operational value would be destroyed if exposed in non-controlled cleanliness areas.

Federal Standard No. 209 has established three classes of clean rooms, each classified according to the maximum number of particles permissible per cubic foot. The specific requirements for the highest operational level clean room (Class 100) are more stringent than those for the other two classes. Class 100 requirements specify that particles 0.5 microns and larger shall not exceed a total of 100 per cubic foot. The Materials Analysis Branch clean room conforms to the Class 100 requirements. It is continually monitored by automatic particle counting equipment.

Ultrasonic cleaners and spray rinses are used within the clean room to prepare specimens for tests, if required, and to maintain cleanliness of tools. Test equipment is provided to allow for tests for pressures (to 20,000 psi), volumes, leakage rates, and other suspect conditions. The equipment includes pneumatic and hydraulic consoles, simulators, manipulators, and such other equipment that may be required for conducting tests within environmental controlled areas. An automatic particle counter is continually available to monitor test liquids.

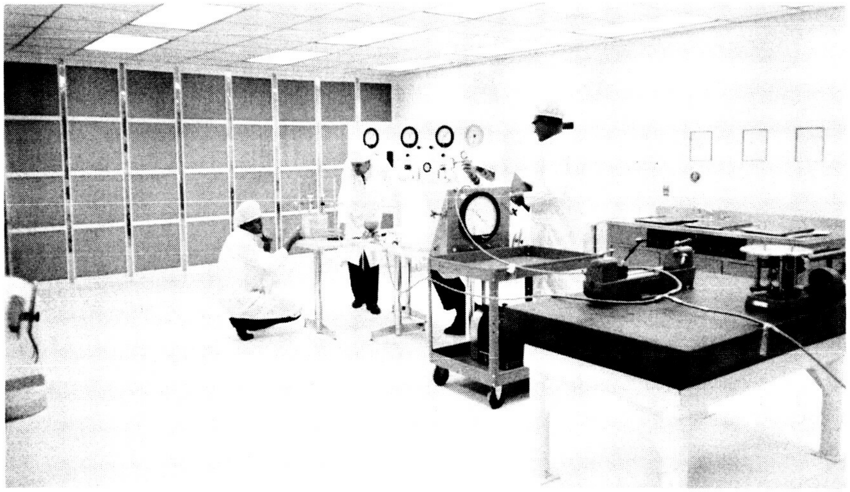

Figure 3.2-1. Class 100 Clean Room Per Fed Std 209 (Par 3.2.1)

3.2.2 X-Ray Image Intensifier System (Figure 3.2-2)

This system is perhaps the best device available today for both "quick look" and detailed malfunction investigative work. It provides the capability for direct viewing, remote viewing, viewing of the test object motionless or in motion, and allows for either still or cine photography of x-ray images of test objects.

The x-ray image intensifier system can accept components up to two cubic feet in volume, and up to 600 pounds in weight. The smallest component acceptable has not been determined; however, a 0.0002 inch diameter gold wire in a semi-conductor has been successfully viewed and photographed.

An observer may examine an object by direct view through fluoroscopic means. A fluorescent screen between the object and the viewer permits the viewer to make direct observations of the x-ray image of the object. A special handling table is available which may be used to obtain motion relative to the viewing screen. This table allows three degrees of motion and can be tilted and rotated. Fluoroscopic viewing is best suited for components such as small servo mechanisms, transistors, and so forth.

X-ray image intensification uses light intensifiers, an optical magnifier, and a TV camera in the enclosed test area. A vidicon TV monitor is utilized for remote viewing. As with the fluoroscopic method, a special handling table permits viewing of the test object in motion.

Photographic attachments can be used with either the fluorescent screen or the TV monitor. These attachments include a 4 by 5 negative plate, a Polaroid camera for plate film, and a high speed motion camera for cine photography. The cine car a has a speed range from 6 to 500 frames per second.

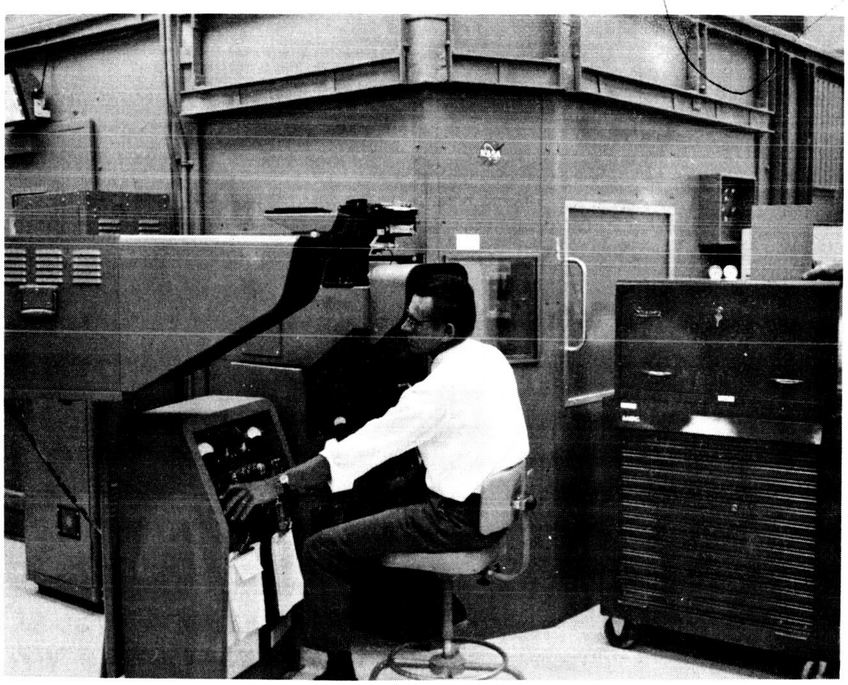

Figure 3.2-2. 250 KVP X-Ray Image Intensifier and Vidicon (Par 3.2.2)

3.2.3 Optical Comparator (Figure 3.2-3)

This instrument will view an object as large as 10 inches by 10 inches by 10 inches up to a magnification of 200X. The magnified view can either be a shadow or a true image. The purpose of this instrument is for measurement of components to an accuracy of $\pm$ .0001 inch.

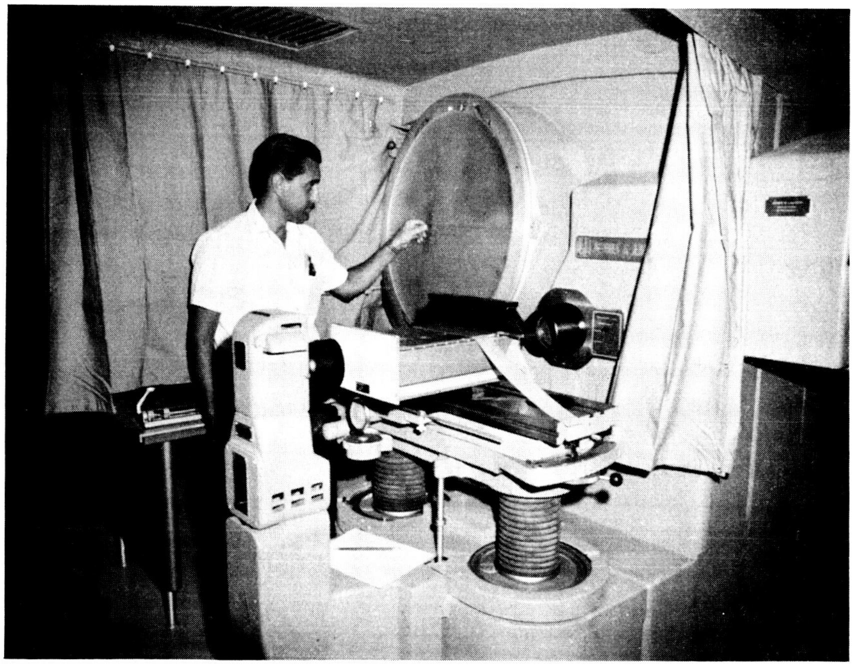

Figure 3.2-3. Optical Comparator - 30 inch (Par 3.2.3)

3.3 MALFUNCTION INVESTIGATION SUPPORT LABORATORY (Figure 3.3-1)

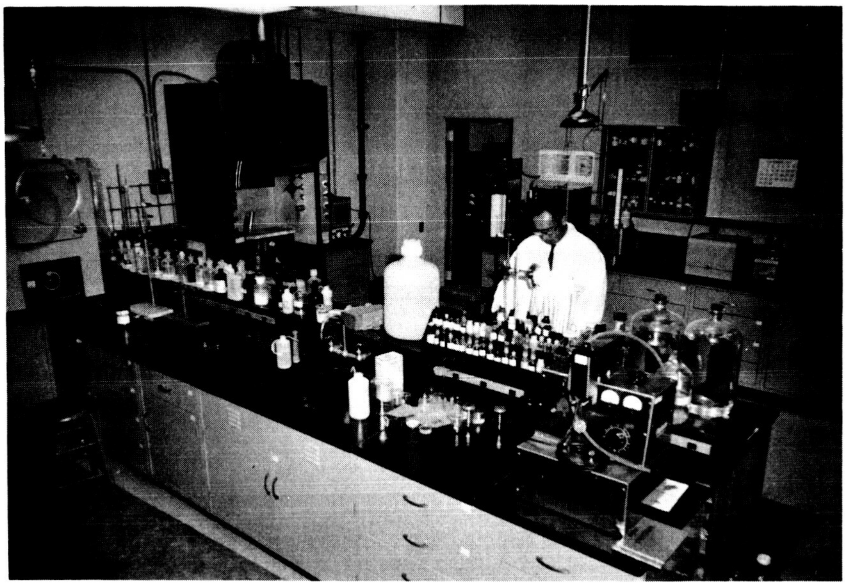

Figure 3.3-1. General Chemistry Laboratory (Par 3.3)

3.3.1 Analytical Instrumentation

The Analytical Instrumentation area has the following equipment available for conducting chemical analysis.

3.3.2 CEC Model 21-110 Mass Spectrometer (Figure 3.3-2)

This is a high resolution, double focusing mass spectrometer which is used to identify material through determination of the molecular weight, isotope distribution, and fragmentation pattern of the compounds in the test specimen. The mass range is from 2 to 2000.

Depending on the mode of operation, the mass spectrometer can provide either qualitative or quantitative information. In the high resolution gas source mode, for instance, qualitative information can be obtained on any substance having a vapor pressure of 10^{-3} torr at a temperature as high as $350^{o}C$. In the spark source mode, both qualitative and quantitative information can be obtained on nonvolatile inorganic materials.

Mass spectrometric analyses are relatively rapid, and provide precise and accurate information on any material that can be vaporized.

Tests may be recorded either photographically or on strip chart recorders, depending on the source mode of the test.

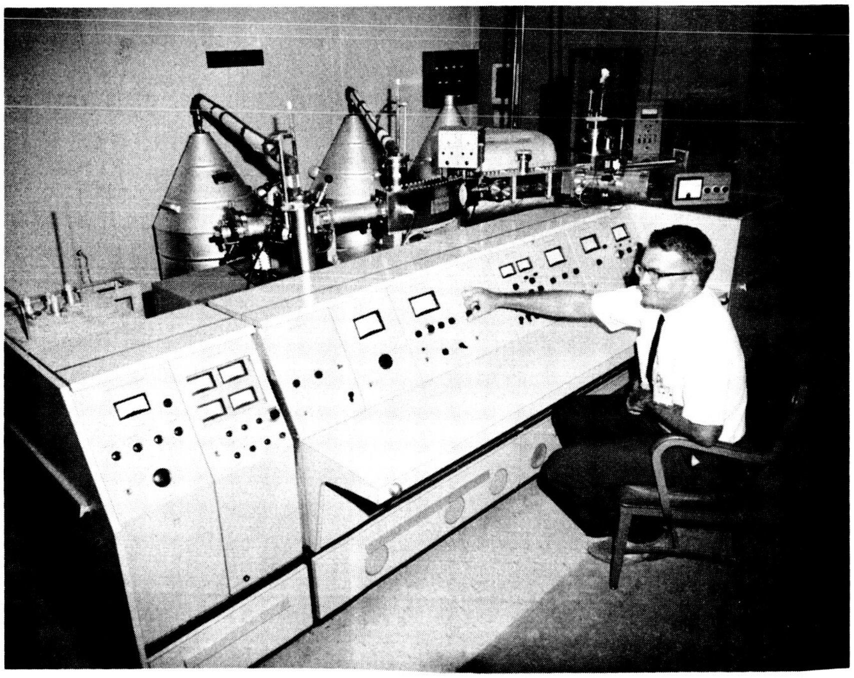

Figure 3.3-2. Spark Sounce Mass Spectro Graph (Par 3.3.2)

3.3.3 <u>Jarrell-Ash 3.4 Meter Ebert Optical Emission Spectograph (Figure 3.3-3)</u>

This particular spectograph will provide both qualitative and quantitative information for some 40 to 60 elements, primarily metals. It is used for analyzing and identifying metallic elements and metallic constituents of organic and inorganic compounds or mixtures of both.

A plasma source and a laser source, in addition to all common modes, are available for excitation of the elements.

The technique employed by the spectrograph is destructive and requires that the test sample be burned.

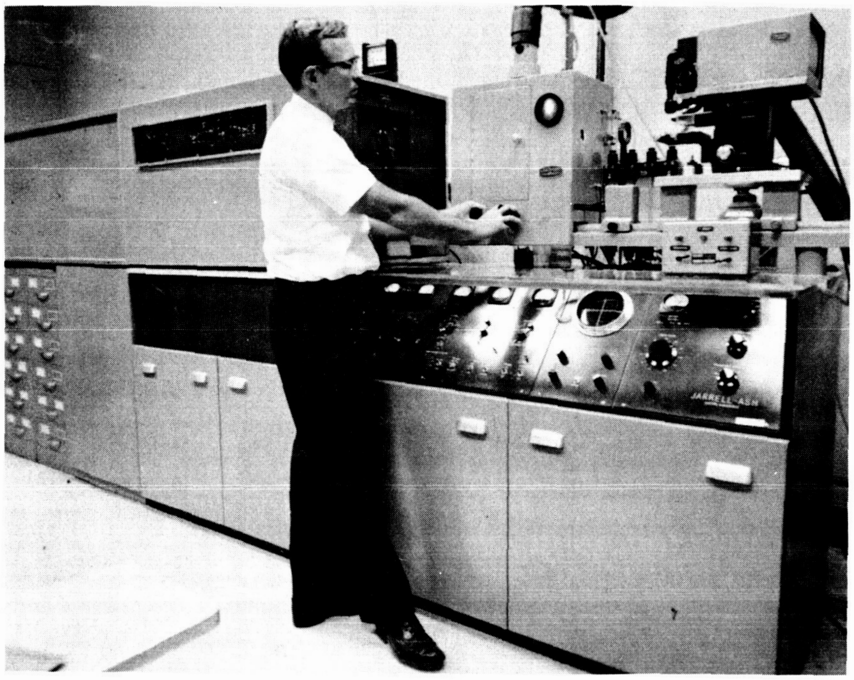

Figure 3.3-3. Optical Emission Spectrograph (Par 3.3.3)

3.3.4 Beckman Model DK2A UV-VIS-NIR Spectrophotometer

Primarily, this is a device for obtaining the wavelength of material in the 170 to 3500 millimicron range. It is used to produce quantitative information rather than qualitative, using samples that are liquid or soluble in a liquid and where the energy absorbed falls within the spectral range previously mentioned.

The entire absorption spectrum of the sample can be obtained with the spectrophotometer.

3.3.5 Perkins-Elmer Model 221 Infra Red Spectrophotometer

This instrument is used for measuring the absorption spectra of compounds in the 200 to 15,000 millimicron wavelength range. Its primary use is to provide qualitative information on samples that are liquid or soluble in a liquid, but it is equipped to work with gases and conditioned solids.

3.3.6 Hitachi Model HU 11A Electron Microscope (Figure 3.3-4)

The electron microscope is used for the study of solid materials that require higher magnification than is obtainable with light microscopes, and for electron diffraction identification. With this instrument, direct magnifications as high as 250,000X are possible; photographic enlargements to 2.5 million X are possible.

The electron microscope is capable of identifying extremely small quantities of crystalline materials by electron diffraction techniques.

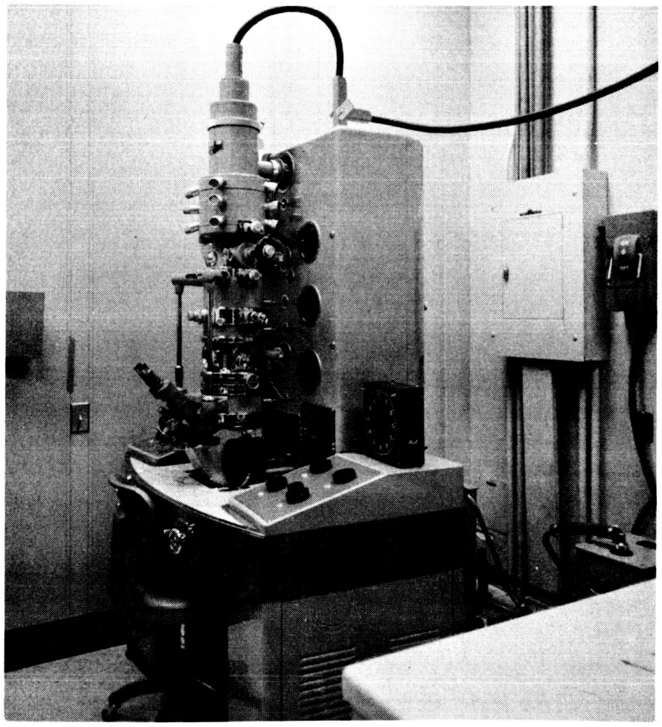

Figure 3.3-4. Electron Microscope (Par 3.3.6)

3.3.7 Applied Research Laboratory Model EMX Electron Microprobe (Figure 3.3-5)

The microprobe provides quantitative and qualitative information about the composition of surfaces, or of very minute particles. It can, for example, by measuring the composition of a very small area, distinguish relations between composition and location within grains or across grain boundaries,etc.

The microprobe is capable of analyzing an area as small as 0.5 micron square, and can determine concentrations of 1000 ppm in the area analyzed. It can detect all but 10 of the elements.

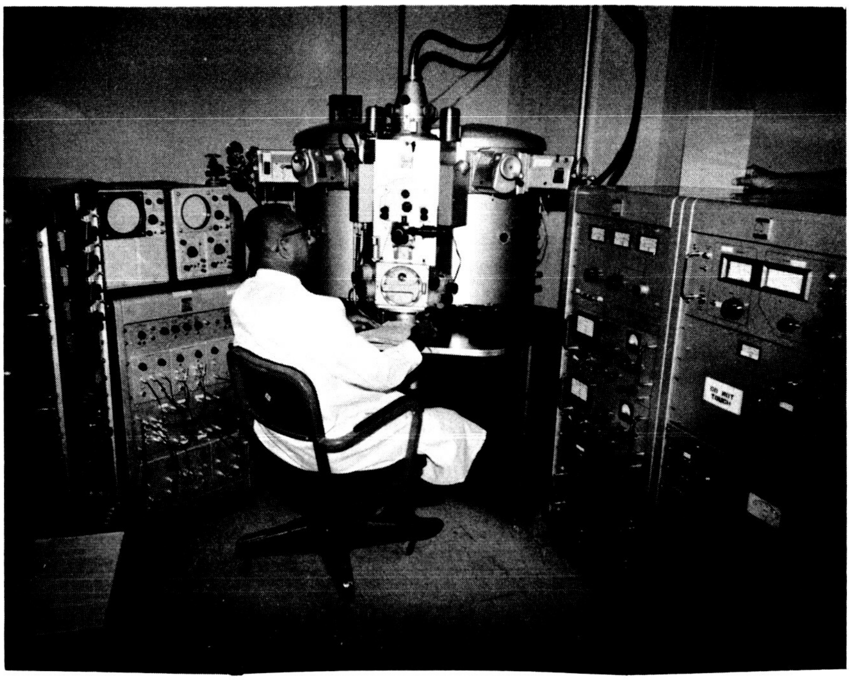

Figure 3.3-5. Electron Microprobe (Par 3.3.7)

3.3.8 Phillips Electronics X-Ray Diffraction/Fluorescence Unit (Figure 3.3-6)

This unit is used for qualitative and quantitative determinations of elements and compounds. Qualitative information on compounds is obtained by diffraction techniques using an empirical approach and requiring reference data of crystallographic properties of known materials. The diffraction technique is both rapid and non-destructive and data can be determined from a sample only a few micrograms in size. Fluorescence techniques are employed for the analysis and identification of elements. Quantitative information, based on previously established standards can be obtained. The fluorescent technique is precise and extremely rapid.

Permanent records of analyses and tests conducted with this unit may be made by strip charts or photographs.

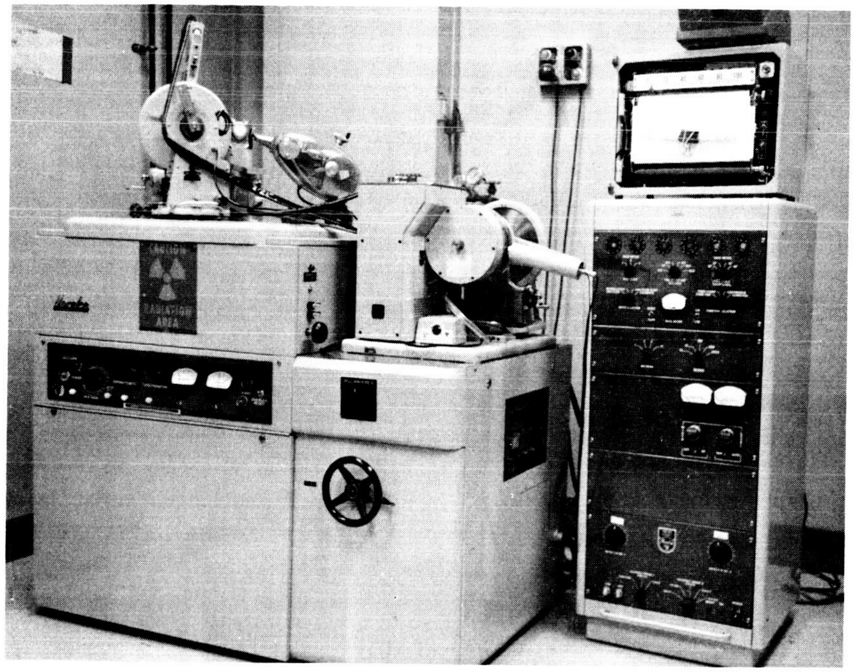

Figure 3.3-6. Diffraction/Flourescence Unit (Par 3.3.8)

3.3.9 Micro-Tek Gas Chromatograph (Figure 3.3-7)

The gas chromatograph is used to separate individual components from highly complex mixtures and to provide precise quantitative estimates of their concentration. Samples, either gas or liquid, must be volatile at temperatures below about 400°C. The chromatograph is extremely sensitive for organic compounds, many of which can be detected at concentrations of less than 1 ppb, consequently the instrument requires a very small sample.

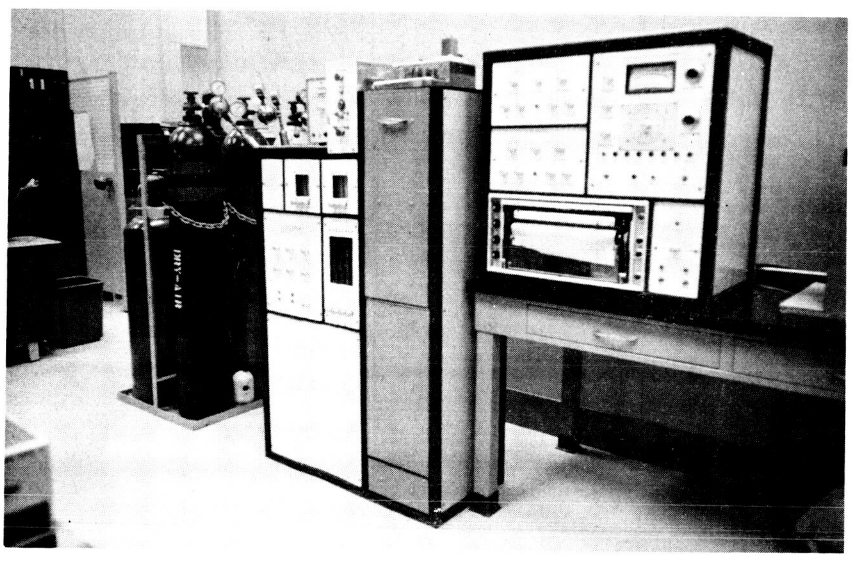

Figure 3.3-7. Gas Chromatograph (Par 3.3.9)

3.4 MATERIALS TEST LABORATORY

3.4.1 Mechanical Test Equipment

Mechanical test equipment available to the laboratories is similar to that found in other organizations of comparable size. This equipment is used to perform malfunction investigative work as well as to prepare samples for analysis. Some of the testing equipment used for mechanical testing is described in the following paragraphs.

3.4.2 Universal Testing Machines (Figures 3.4-1 and 3.4-2)

Two machines are in use, one has a capacity of 2 grams to 15,000 pounds and the second 1 ounce to 120,000 pounds full scale. These machines provide a force-measuring system that can apply tensile and compressive loads. Temperatures can be controlled from $-300^{o}F$ to $+600^{o}F$ under test conditions.

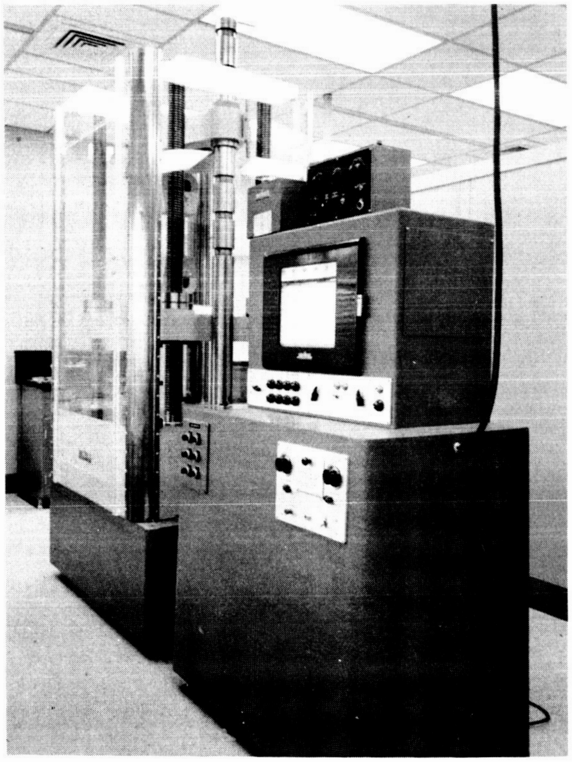

Figure 3.4-1. Universal Tester 2 Grams to 15,000 Pounds (Par 3.4.2)

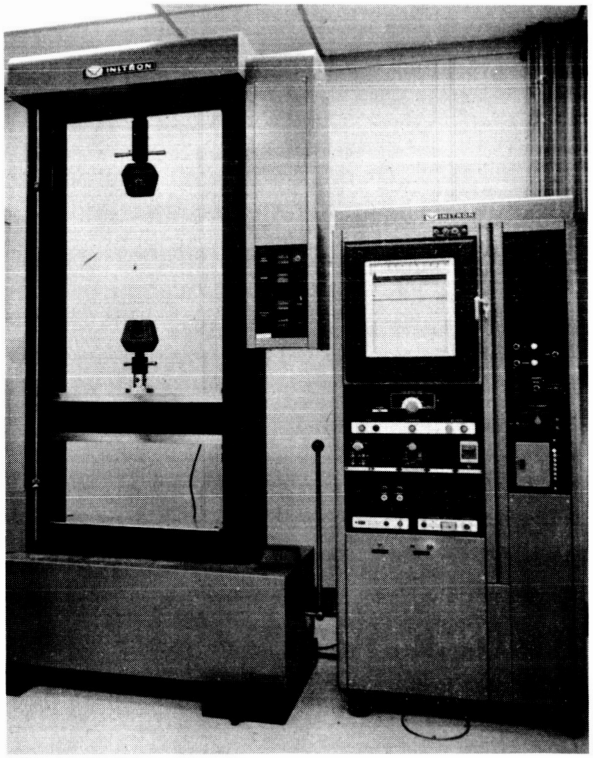

Figure 3.4-2. Universal Tester Tensile and Compressive Tests from 1 Ounce to 120,000 Pounds (Par 3.4.2)

3.4.3 Metallograph (Figure 3.4-3)

This instrument is used for making microscopic studies of organic and inorganic materials. With various light sources, magnifications from 35x to 2800x are possible.

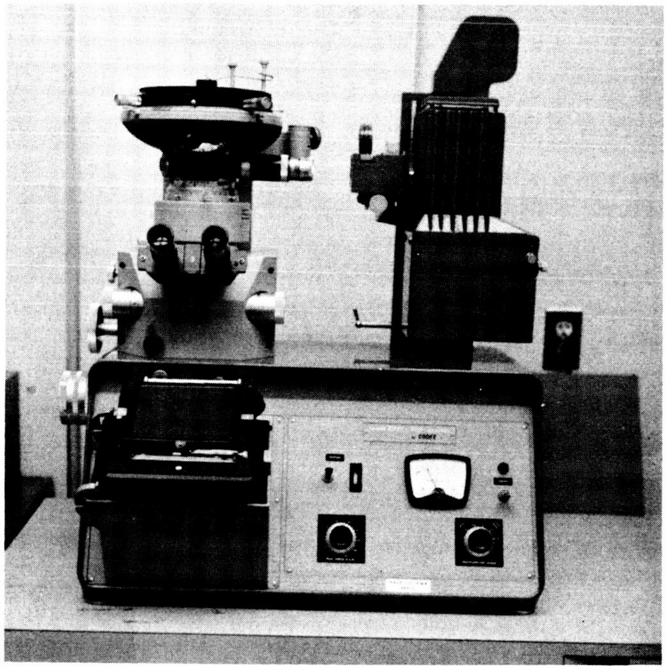

Figure 3.4-3. Vickers Metallograph for Examination of Metallurgical Samples (Par 3.4.3)

3.4.4 Hardness Testers

Testers are available for determining the hardness values of metallic materials and surface coatings. Included are:

a. A Macro tester for determining the Rockwell hardness values of metallic materials and providing a direct readout on a dial indicator.

b. A Micro tester for determining the hardness of surface coatings or polished surfaces under controlled loading conditions with respect to amount and duration.

c. A portable tester, similar to the Macro tester, that can be used at any location. It is limited on the size of the specimen that can be tested.

3.4.5 Disassembly Lathe and Milling Machine

These are special application machines, used for the controlled relationship disassembly of parts and components and for the removal of potting, enclosures, and precision alignment operations, respectively. The lathe can be fitted with borescope and camera mounts to facilitate malfunction investigations.

3.4.6 Strain Gage Bond Set-Up

Equipment for installing strain gages on devices undergoing investigation and the related load carrying fixture elements are included in this category.

3.4.7 Special Work Tables

Several special design work tables are available for the laboratories. A granite surface table is available, for instance, to provide a suitable surface for precision alignment in tests and test set-ups. Also included is a systems demounting table which is, essentially, a clean hooded work area having fittings for holding parts in selected positions during a disassembly or assembly operation.

3.4.8 Sample Preparation Equipment

Numerous equipments are available for preparing specimens for metallographic, microscopic, and analytical examination. Included in this category are surfacers, grinders, polishers, etchers, and mixers.

3.5 NON-DESTRUCTIVE TEST EQUIPMENT

Major equipments, their principles of operation and application, for conducting non-destructive tests are described in the following paragraphs.

3.5.1 Radiography (Figure 3.5-1)

3.5.1.1 Portable X-Ray Equipment (Figure 3.5-2)

The Non-destructive Testing Laboratory has six portable X-ray units; two capable of operating at an accelerating voltage of up to 200 KVP, two capable of operating at an accelerating voltage of up to 140 KVP. Also one 5 to 40 KVP and one 40 to 90 KVP. Depending on the generator power, these X-ray units can be used on objects from paper thin to several inches thick. These units are principally used for subsurface detection.

Figure 3.5-1. Equipment for Interpreting Radiography Film (Par 3.5.1)

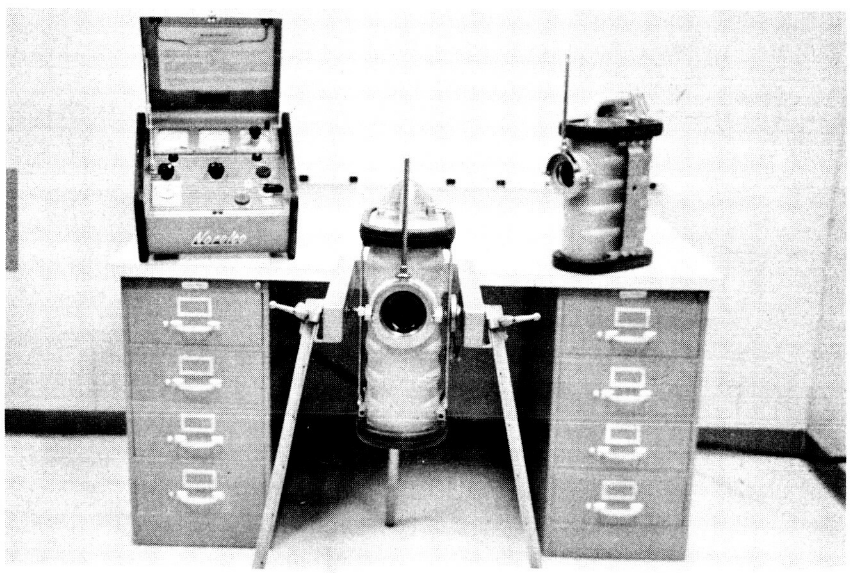

Figure 3.5-2. Portable X-Ray Equipment (Par 3.5.1.1)

3.5.1.2 Radioisotopes (Figure 3.5-3)

The radio active Isotope consist of Iridium 192 and Cobalt 60. These are capable of radiographing material such as stainless steel up to 7 inches in thickness. The equivalent maximum KVP range is 1.2 MEV.

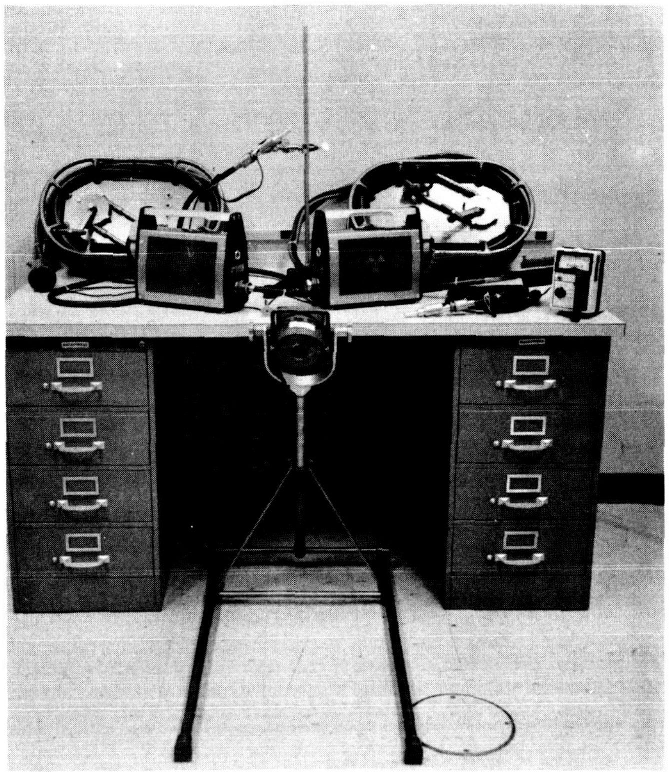

Figure 3.5-3. Portable Radioisotopes Equipment (Par 3.5.1.2)

3.5.2 Magnetic Particle Inspection Unit

This is a unit that can be used on materials that can be magnetized. By spraying a test specimen with particles (which attract along lines of force), cracks, seams, inclusions, and voids at or near surfaces of the test specimen can be visually detected.

3.5.3 Penetrant Kit, Portable

Using this test method, fluorescent dye is used on a test specimen for detecting cracks, porosity, and lack of bond at exposed edges. This method of flaw detection can be used on most solids and on many shapes and sizes of test specimens. Its detection sensitivity is limited to crack width of 4 by 10^{-6} inch.

3.5.4 Ultrasonic Flaw Detector (Figure 3.5-4)

The Ultrasonic Flaw Detector is an excellent device for crack detection. It transmits ultrasonic waves through a test specimen and the reflected waves will reveal the depth of a crack and, through manipulation of the probe, can determine the entire area of discontinuity. This detector can be used for relatively thick sections of homogenous materials since its detection capability ranges from 1/8 inch to several feet.

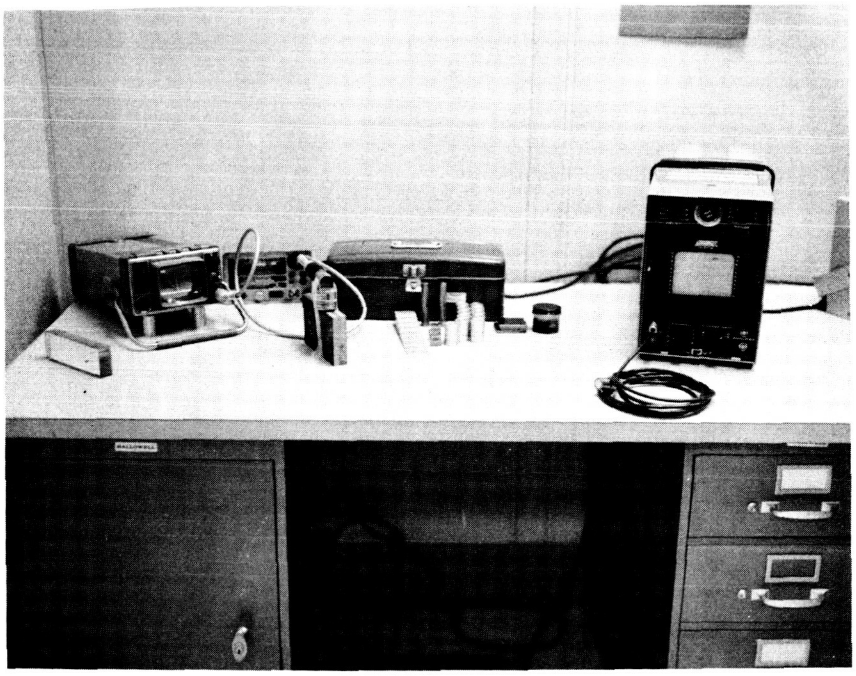

Figure 3.5-4. Ultrasonic Flaw Dectector (Par 3.5.4)

3.5.5 Eddy Current Unit (Figure 3.5-5)

The eddy current method is used principally to measure the depth of cracks and other discontinuities that cannot be detected by penetrants. In addition to locating cracks, this unit can be used to sort material for physical properties such as hardness, heat treat, alloy and conductivity in both magnetic and nonmagnetic materials. It is also an excellent device for measuring the thickness of conductive coatings on nonmagnetic sheet and foil.

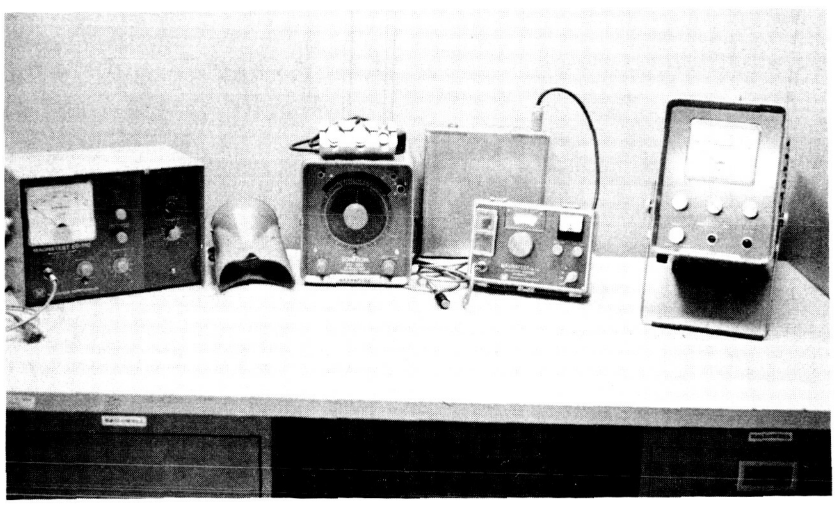

Figure 3.5-5. Portable Eddie Current Equipment (Par 3.5.5)

3.6 ENVIRONMENTAL TEST EQUIPMENT

Most known environments and operating characteristics can be simulated with the test equipment available to the Environmental Testing Laboratory. The following paragraphs describe the test equipment in full detail.

3.6.1 MB Electronics Model C-50 Electrodynamic Vibration Exciter (Figures 3.6-1 and 3.6-2)

The MB Model C-50 is a 5000 lb. force, oil-cooled, high frequency vibration exciter designed for use in the frequency range from 5 to 3000 cps. The fundamental axial resonant mode of the moving element is above 3000 cps with the test table unloaded. The full 1-inch double amplitude is rated on a continuous duty basis. The power amplifier provides for full force output with minimum distortions over the entire frequency range of the exciter.

An MB/ARA 202B-2 Vibration Test Table can be used with this exciter for horizontal testing of test specimens.

The MB Model T130 Since Control Console provides for automatic control of displacement and acceleration levels while automatically sweeping the frequency spectrum.

The MB Model T388 Automatic Random Equalyzer/Analyzer provides accurate equalization of the frequency spectrum using the technique of multiple, narrow-bandpass filters in parallel. Eighty filters each of 25 cps bandwidth are used to cover the frequency ranges of 10 cps to 2 kc to 4 kc, or 4 kc to 6 kc. The equalizer has a dynamic range of 40 db and an equalization time of approximately 5 seconds. Typical equalizations are flat within $\pm$ 1.5 db. The system has the capabilities of producing either flat or shaped spectra, accepting taped inputs, and can be used for mixed sine/random testing.

3.6.2 MB Electronics Model C-10E Electrodynamic Vibration Exciter and Model T351-1 Amplifier/Sine Control Console (Figures 3.6-1 and 3.6-2)

The MB Model C10E is a 1200 lb. force, air-cooled, high frequency vibration exciter designed for use in the range from 5 to 3000 cps. The fundamental axial mode of the moving element is about 3000 cps with the table unloaded. The full 1 inch double amplitude is rated on a continuous duty basis. The Model T351-1 electronic amplifier and control console provides for full force output with minimum distortion over the operating range of the exciter. The control console provides for automatic control of displacement and acceleration levels while automatically sweeping the frequency spectrum.

Figure 3.6-1. Electrodynamic Vibration Exciter Room Showing Models C-10 and C-50 Vibration Exciters (Par 3.6.1 and 3.6.2)

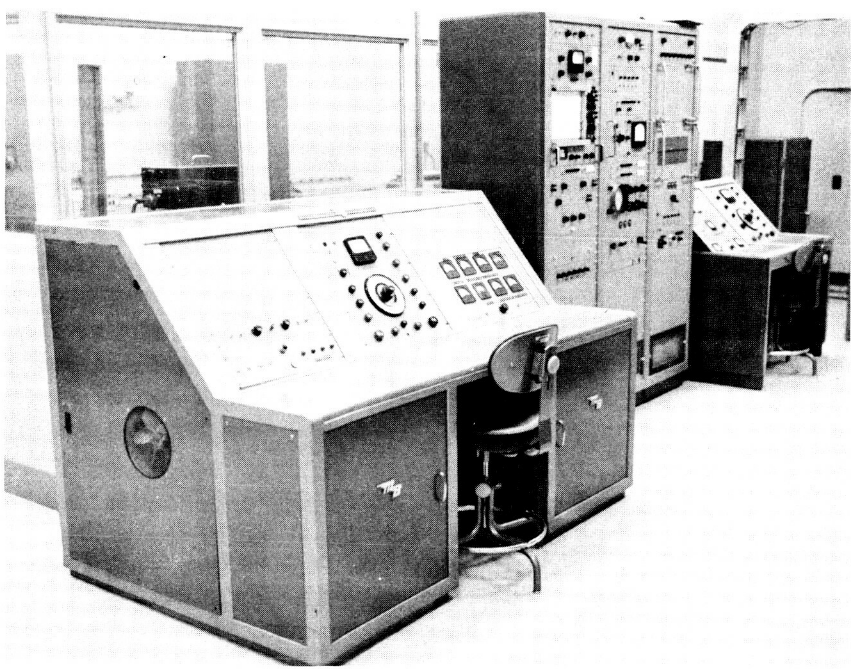

Figure 3.6-2. Electrodynamic Vibration Exciter Controls and Amplifiers Models T-130, T-388 and T351-1 (Par 3.6.1 and 3.6.2)

3.6.3 Avco Type SM-030-1 Shock Test Machine (Figure 3.6-3)

The Avco type SM-030-1 Shock Test Machine is a free-fall shock testing device composed of four major components; base, anvil, carriage, and superstructure. Shock pulses are obtained by impact of the carriage assembly against a deceleration device. Deceleration devices range from molded lead pellets to solid rubber pads. The machine is capable of producing half-sine, sawtooth, and a variety of other shock waves up to 500 times the force of gravity at shock pulse durations of 2 to 30 milliseconds. The shock machine accommodates large test loads up to 36 by 36 by 78 inches and weighing up to 1000 lbs. A rebound control device is used to prevent multiple shocks.

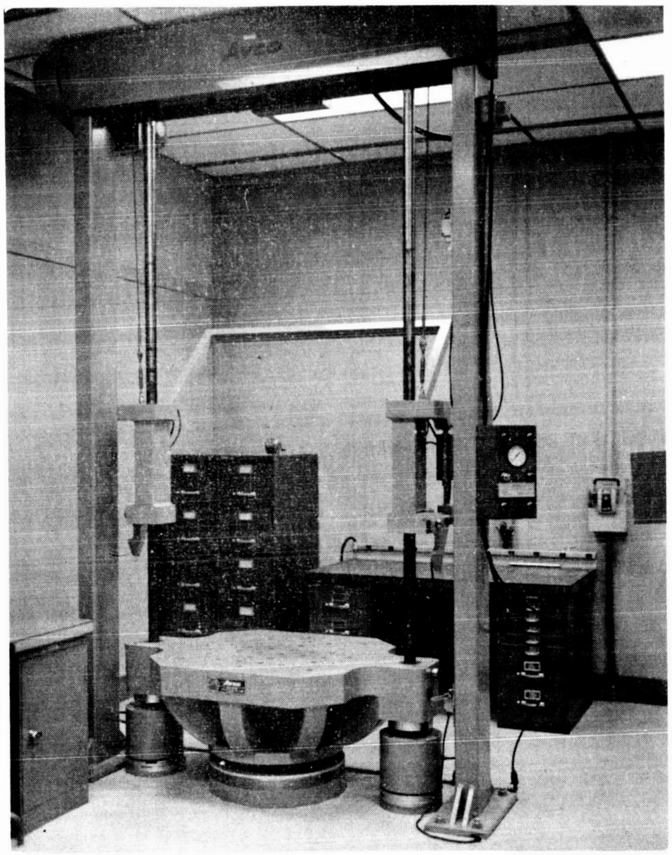

Figure 3.6-3. Shock Test Machine 1000 Pound Capacity (Par 3.6.3)

3.6.4 Avco Type SM-010-3 Shock Test Machine (Figure 3.6-4)

The Avco Type SM-010-3 shock machine is a smaller version of the SM-030-1 shock machine described previously. The maximum acceleration this machine is capable of producing is 3000 g's. Shock pulse durations are variable from 0.2 to 22 milliseconds. The maximum specimen size is 12 by 12 by 17 inches. The maximum specimen weight is 100 pounds.

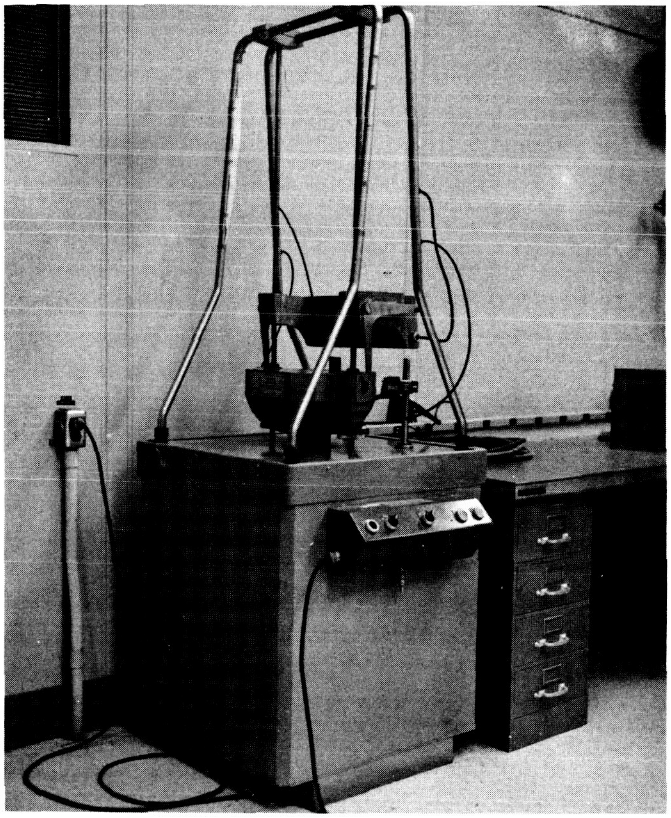

Figure 3.6-4. Shock Test Machine 100 Pound Capacity (Par 3.6.4)

3.6.5 Schaevitz Machine Works Type 263-9 Centrifuge (Figure 3.6-5)

The Schaevitz Type 263-9 is a heavy-duty, servo controlled, hydraulic centrifuge with a centrifugal force rating of 15,000 g-lbs. A control console contains the necessary instrumentation for the servo-actuator control system. Fast, stable response is obtained with accurate control of the acceleration level. Slip rings are provided for supplying electrical power and pneumatic and hydraulic pressure to the test specimen. The centrifuge has an acceleration range of 0 to 200 g's at 42-inch nominal radius, a weight capacity of 150 pounds dead weight at each end of boom, a test package maximum size of 24-inch cube and an accuracy within 0.25% at any speed setting from 1 g to 200 g over a one minute period.

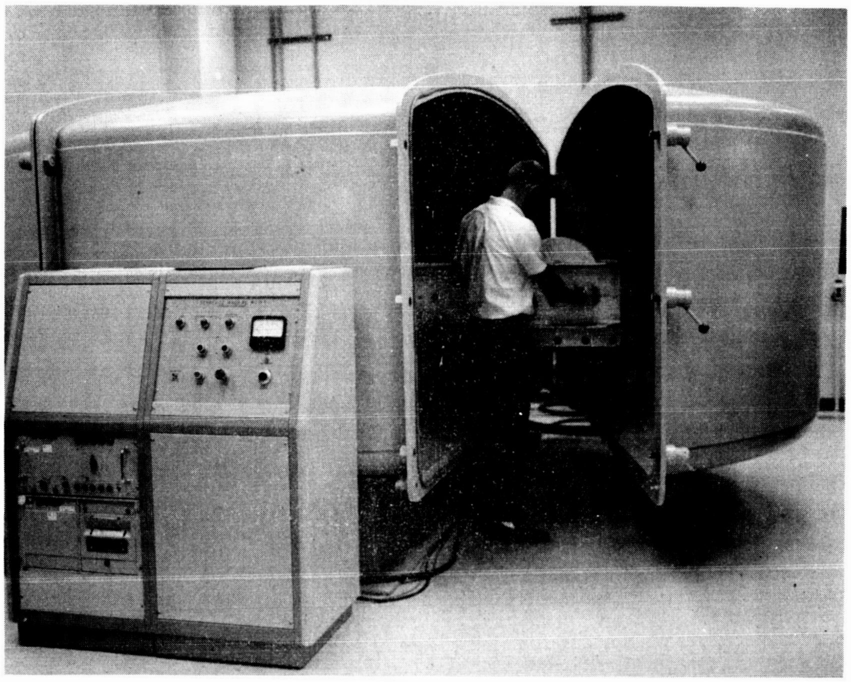

Figure 3.6-5. Centrifuge 150 Pound Capacity (Par 3.6.5)

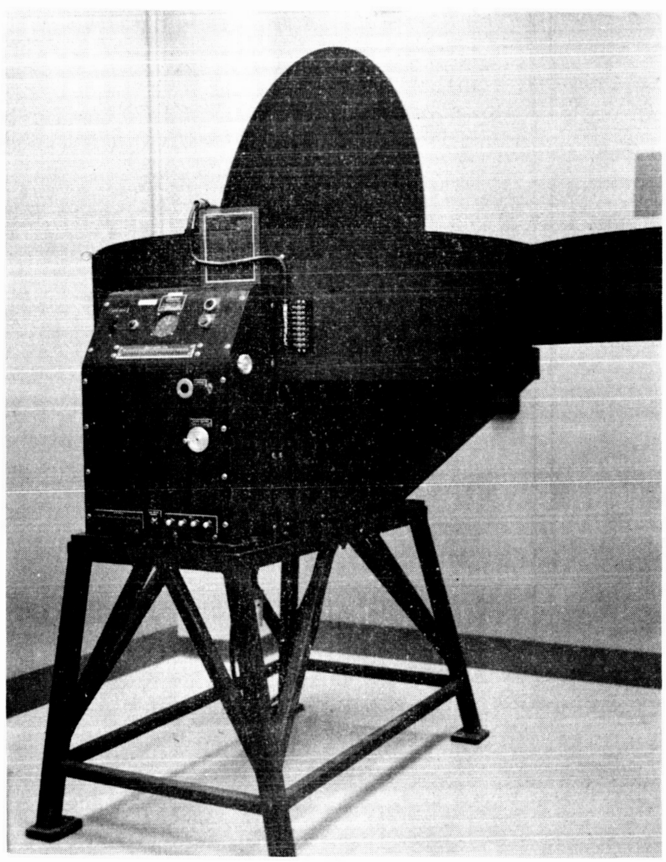

Figure 3.6-6. Centrifuge 25 Pound Capacity (Par 3.6.6)

3.6.6 Genisco Model B-78 Centrifuge (Figure 3.6-6)

This centrifuge is similar to, but smaller than, the Schaevitz centrifuge previously described. A centrifugal force capacity of 1200 g-lbs., sixteen electrical slip-rings, and four pneumatic-hydraulic glands are available. The centrifuge has an acceleration range of 0 to 100 g's at 24 inch nominal radius, weight capacity of 25 pounds dead weight, a maximum test package size 8 inch cube. Accuracy (variation from set speed) WOW 0.5% maximum above 10 rpm, and Drift 0.1% maximum per minute above 10 rpm. Sixteen slip rings, rated at one ampere each, are provided and four pneumatic hydraulic glands are provided. These glands are rated for 100 psi peak allowable pressure and may be used to supply air or other fluids under vacuum or pressure conditions to the test objects.

3.6.7 High Vacuum Equipment Corporation Model 8018 Bell Jar System (Figure 3.6-7)

This system is a self contained unit consisting of an 18-inch by 30-inch bell jar, roughing pump, 4-inch diffusion pump, controls and valving. A thermocoupleonization gage is used for instrumentation. The polished stainless steel baseplate is equipped with a number of feedthroughs and connections.

A large liquid nitrogen and water cooled baffle arrangement assures absolute cleanliness in the bell jar. The system has the capability of providing an ultimate pressure of 8 by 10^{-8} in the bell jar and has feedthrough connections as follows:

(a) One rotary push-pull for full rotary motion plus 4 inch vertical translation
(b) Two gas or liquid low thermal loss re-entrant type feedthroughs
(c) Eight iron-constantan thermocouple feedthrough
(d) An induction feedthrough with water-cooled leads
(e) Eight low voltage feedthroughs (10 amps)

3.6.8 Tenney Engineering Model 27ST-100350 Temperature-Altitude Chamber (Figure 3.6-8)

This chamber is a custom designed facility designed to simulate thermal and altitude conditions either separately or simultaneously. The chamber has been constructed to be compatible with a 100% oxygen atmosphere.

The chamber is equipped with electric air heaters for high temperature and a cascaded Freon 13/22 refrigeration system for low temperatures. A gas-ballasted mechanical vacuum pump produces the vacuum capabilities. The chamber has an interior capacity of 27 cubic feet (3 by 3 by 3 feet), temperature range of -100°F to +350°F, and an altitude range of site level to 200,000 feet.

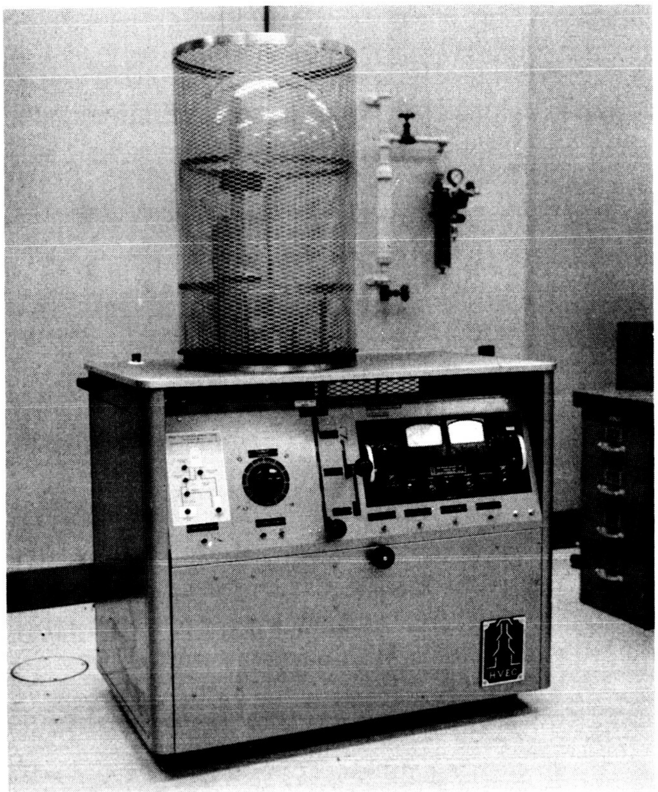

Figure 3.6-7. Vacuum Bell Jar (Par 3.6.7)

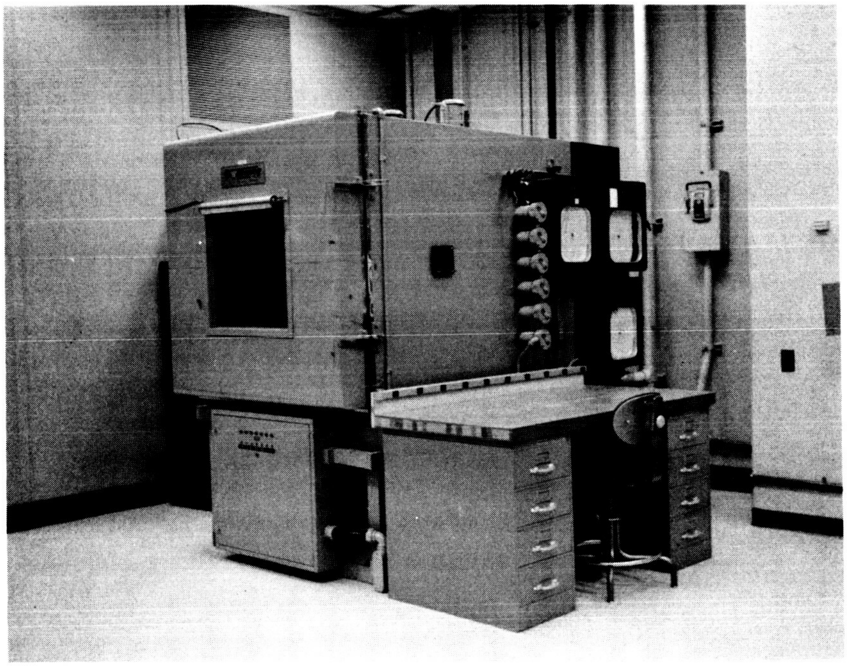

Figure 3.6-8. Temperature-Vacuum Chamber 27 cu. ft. (Par 3.6.8)

3.6.9 Tenney Engineering Model TMST-3-100350 Temperature-Altitude Chamber (Figure 3.6-9)

This chamber is capable of subjecting test components to thermal and vacuum conditions either separately or simultaneously. The chamber has electric air heaters for high temperature and a cascaded Freon 13/22 refrigeration system for low temperatures. In addition, liquid CO_2 can be injected into the chamber for quick temperature pull down. Two mechanical vacuum pumps produce the vacuum capabilities. One 2-1/2 inch port is located on the chamber side wall. The chamber has an interior capacity of 18 inch wide by 18 inch deep by 22 inch high, temperature range of -100°F to +400°F and an altitude range of site level to 100,000 feet.

3.6.10 Tenney Engineering Model T27UFR-100350 Temperature-Humidity Chamber (Figure 3.6-10)

This chamber is capable of producing conditions of high or low temperatures, high temperature with high or low humidity, and intermediate temperatures with high or low humidity. The chamber is equipped with electric air heaters for high temperature and a cascaded Freon 13/22 refrigeration system for low temperatures. One 4-1/2 inch and one 2-1/2 inch diameter instrumentation ports are located on the chamber sidewalls. The chamber has an interior capacity of 27 cubic feet (3 by 3 by 3 feet), a temperature range of -100°F to +350°F and a humidity range of 5% to 95% R.H. as limited by a minimum dew point of 35°F and a maximum dry-bulb of 185°F. Five percent R.H. can be obtained from 160°F to 185°F.

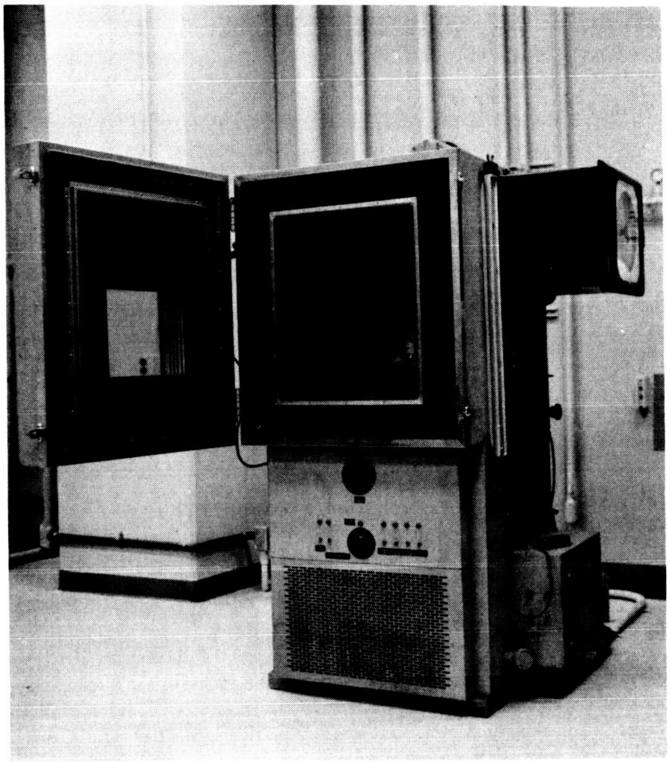

Figure 3.6-9. Temperature-Vacuum Chamber 18 in. by 18 in. by 22 in. (Par 3.6.9)

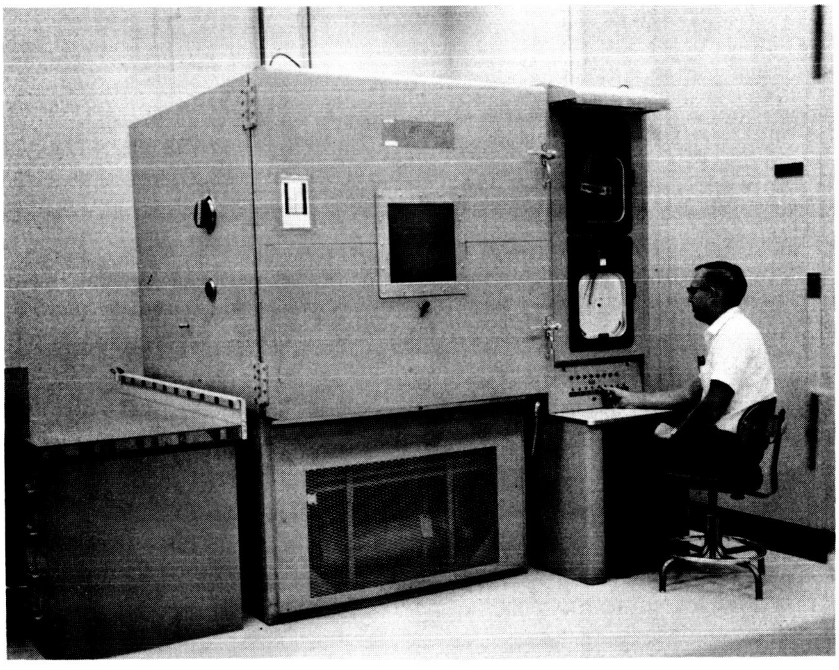

Figure 3.6-10. Temperature-Humidity Chamber of 27 cu. ft. (Par 3.6.10)